OPTICAL DISCS FOR MEASURING ANALYTES

This application claims priority from U.S. Provisional Application Serial No. 60/254,394, filed December 8, 2000; U.S. Provisional Application Serial No. 60/255,233, filed December 12, 2000; U.S. Provisional Application Serial No. 60/293,917, filed May 24, 2001; U.S. Provisional Application Serial No. 60/294,051, filed May 29, 2001; U.S. Provisional Application Serial No. 60/294,052, filed May 29, 2001; U.S. Provisional Application Serial No. 60/303,437, filed July 6, 2001; U.S. Provisional Application Serial No. 60/306,226, filed July 18, 2001; and U.S. Provisional Application Serial No. 60/323,405, filed September 19, 2001.

FIELD OF THE INVENTION

This invention relates to optical discs configured to receive analytes which can be detected by a standard optical disc reader or an optical disc reader modified therefrom.

BACKGROUND OF THE INVENTION

Optical discs have been used for detection and characterization of biological and chemical samples. For instance, see WO 96/09548 (Gordon), EP A 392475 (Idemitsu), EP A 417 305 (Idemitsu), EP A 504432 (Idemitsu), and WO 98/12559 (Demers), all of which are incorporated herein by reference. Other examples of using optical discs to detect investigational samples can be found in U.S. Provisional Application 60/252,725, entitled "Optical Bio-Disc Including Microfluidic Circuit For Separation And Quantification Of Agglutinated Microparticles Or Cells And Methods Relating Thereto," U.S. Provisional Application No. 60/252,726, entitled "Bioactive Solid Phase For Specific Cell Capture And Optical Bio-Disc Including Same," and U.S. Provisional Application No. 60/257,705, entitled "Surface Assembly For Immobilizing DNA Capture Probes And Bead-Based Assay Including Optical Bio-Discs And Methods Relating Thereto," all of which are incorporated herein by reference.

These previously described optical discs, however, are not designed to be read by standard optical disc readers, such as standard CD or DVD readers. For instance, the optical discs disclosed in EP A 392475 (Idemitsu), EP A 417 305 (Idemitsu) and EP A 504432 (Idemitsu) require the use of two optical detectors, one to detect the tracking information and

the other to detect surface structures. In contrast, reading a standard CD or DVD needs only one optical detector.

Therefore, there is a need to design and manufacture an optical disc configured to receive an investigational sample which can be detected by a standard optical disc reader or an optical disc reader modified therefrom.

Over the past decade, scanning laser microscopy (SLM) has revolutionized life science imaging. However, SLM demands expensive and specialized optical equipment. Consequently, there exists a need to provide an inexpensive, generic device which can carry out laser scanning over microscopic specimens.

The present invention discovers that the minimum mechanical requirements for SLM, i.e. laser, focusing and detection optics, precision scanning means, and computer interface, may all be provided by a standard optical disc reader or an optical disc reader modified therefrom. Therefore, it is desirable to create an optical disc which can hold a microscopic sample that can be scanned by a standard optical disc reader. Such an optical disc presents a marked advantage over existing SLM technologies.

In order for a standard optical disc reader to operate an optical disc, the optical disc reader is typically required to be able to (1) accurately focus above the operational surface of the optical disc, (2) accurately follow the spiral track or utilize some form of uniform radial movement across the optical disc surface, (3) recover enough information to facilitate a form of speed control, such as CAV, CLV, VBR, CBR, or ZCLV, (4) maintain proper power control by logical information gathered from the optical disc or by signal patterns detected in the operational surface of the optical disc, and (5) respond to logic information that is used to control, for example, the position of the objective assembly, the speed of rotation or the focusing position of the laser beam.

A typical optical disc system uses elements of the optical medium itself to satisfy at least some of these operational requirements. For instance, in a typical CD, the disc substrate is impressed with a spiral track made up of a series of embossed or impressed pits and lands. Light reflected from these pits and lands can be used to generate signals. These signals are used by the optical disc reader to maintain proper focusing and tracking. In a CD-R disc, a wobble groove is used to generate operational signals during disc recording. Dye marks are created during disc recording, and these dye marks may provide the requisite tracking structures during subsequent reading. Generally, under each of conventional optical disc

standards, the structures that encode data may simultaneously serve to provide operational signals that enable an optical disc reader to operate the optical disc.

Conventional optical disc standards make no provision with respect to acquisition of information from investigational features, such as biological or chemical specimens, that are disposed on the disc. Investigational features disposed on the disc may disrupt the tracking of the disc. In addition, investigational features may be sufficiently separated from operational structures, therefore preventing an optical disc reader from tracking the disc and detecting the investigational features concurrently and discriminably.

Therefore, there is a need to provide an optical disc which allows an optical disc reader to detect the investigational features without disrupting the tracking of the disc. There also exists a need to provide an optical disc which allows an optical disc reader to track the disc and read the investigational features concurrently and discriminably.

SUMMARY OF THE INVENTION

In one embodiment, an optical disc assembly is configured to associate with an analyte which can be detected by a standard optical disc reader or an optical disc reader modified therefrom.

In another embodiment, an optical disc assembly is configured to associate with an analyte, and the association with the analyte does not prevent an optical disc reader from tracking the disc assembly.

In yet another embodiment, an optical disc assembly, which is associated with an analyte, is configured to enable an optical disc reader to track the disc assembly and detect the analyte concurrently and discriminably.

In accordance with one aspect of this invention, the optical disc assembly includes (1) optically readable structures which are trackable by an optical disc reader and which have encoded speed information enabling the optical disc reader to rotate the optical disc at a speed that is determinable from the speed information; and (2) an analyte section capable of receiving an analyte which can be detected by the optical disc reader. The optically readable structures may be impressed in the operational surface and coated with a reflective layer. The optical disc reader may be a CD or DVD reader. The optically readable structures can be in a CD format or a DVD format.

The analyte section may include at least one analyte chamber located within the disc assembly, such as between the operational layer and another layer of the disc assembly. At

least one channel may be created in one of the layers of the disc assembly to allow the analyte or other components to enter or exit the analyte chamber. The channel may include a valve regulated by optically readable data encoded in the optical disc assembly. In one embodiment, the analyte section includes a plurality of analyte chambers, each chamber being connected to at least a channel.

In one embodiment, design information of the optical disc assembly is encoded in the disc assembly.

In another embodiment, the disc assembly is a reverse disc including a lens layer capable of focusing the laser beam on the operational surface which is located at the laser-proximal surface of the operational layer.

In yet another embodiment, the operational surface in the reverse disc includes a cut-away area which either lacks operational structures or includes modified operational structures. In addition, the cut-away area may lack reflective coatings.

In a preferred embodiment, the analyte chamber includes a surface which is located within 15 micrometers from the operational surface, preferably located within 15 micrometers from the cut-away area, and which preferably is capable of receiving the analyte.

In another preferred embodiment, the disc assembly is a forward disc. The operational surface is at the laser-distal surface of the operational layer and coated with a semi-transmissive, semi-reflective layer. There is a second layer which is laser-distal to the operational layer and which is coated with another reflective layer. Preferably, the operational surface includes a cut-away area, and the analyte chamber includes a surface which is located within 15 micrometers from the cut-away area. More preferably, the analyte chamber includes the cut-away area. The second layer may lack optically readable structures that have encoded tracking information.

In one embodiment, the analyte section contains the analyte which may be a biological or chemical sample. Preferably, the analyte is located within 15 micrometers from the operational surface.

In yet another embodiment, the analyte section is embedded in the disc assembly and includes a surface which is located within 15 micrometers from the operational surface and which preferably is capable of receiving the analyte.

In one embodiment, the disc assembly has encoded information for conducting an assay on the analyte.

In accordance with yet another aspect of this invention, the optical disc assembly includes (1) a hologram which contains optically readable features that have encoded (a) tracking information, and (b) speed information enabling an optical disc reader to rotate the optical disc at a speed that is determinable from the speed information; and (2) an analyte section capable of receiving an analyte which can be detected by the optical disc reader. The hologram may be reflective or replaceable. The optical disc reader may be a CD or DVD reader.

In one embodiment, at least part of the image plane of the hologram is located within the analyte section. The analyte section may include the analyte which may be positioned within 15 micrometers from the image plane of the hologram. The laser beam may be focused on the image plane of the hologram.

In accordance with another aspect of this invention, an analyte held in the analyte section of the optical disc assembly is detected using a CD or DVD reader. The detection includes the steps of (1) introducing the optical disc assembly into the CD or DVD reader; (2) reading the optically disc assembly; and (3) obtaining a signal which is indicative of the presence of the analyte. Preferably, the signal thus obtained is a quad sum signal.

BRIEF DESCRIPTION OF THE DRAWINGS

All the drawings used herein are given by way of illustration, not limitation, and all the drawing are not drawn to scale.

FIG. 1 demonstrates the functional components of an optical disc assembly according to one embodiment of the present invention.

FIG. 2 shows a cross-sectional view of an optical stack including three layers of refractive material.

FIG. 3 is a cross-sectional view of a compact disc recordable (CD-R) including a polycarbonate layer, a dye layer, and a reflective layer.

FIG. 4 is a diagram showing the geometry of a wobbled groove as it is embossed in an operational surface.

FIG. 5 shows a common arrangement of a reading laser beam relative to a spinning optical disc.

FIG. 6 shows wobbled grooves in a forward wobble optical disc, wherein the wobble grooves are embossed in the laser-distal surface of the operational layer.

FIG. 7 shows a forward wobble disc assembly containing wobbled grooves coated with a reflective layer, wherein the operational surface has a cut-away area.

FIG. 8 shows a cross-sectional view of a forward wobble optical disc assembly with an investigational feature placed on a cut-away area.

FIG. 9 demonstrates a reverse wobble optical disc assembly, wherein the wobble grooves are embossed in the laser-proximal surface of the operational layer.

FIG. 10 presents a cross-sectional view of a reverse wobble disc assembly with an investigational feature placed in the analyte section.

FIG. 11 compares the mastering process for making a forward disc with the mastering process for making a reverse disc.

FIG. 12 further compares the mastering process for making a forward disc to the mastering process for making a reverse disc.

FIG. 13 illustrates a reverse optical disc assembly.

FIG. 14 illustrates an optical pickup used in one embodiment of the present invention.

FIG. 15 depicts a quad detector used in one embodiment of the present invention.

FIG. 16 depicts the positions of investigational structures with respect to the tracks of operational structures.

FIG. 17 shows the HF signals acquired from the tracks illustrated in FIG.16.

FIG. 18 shows an optical disc assembly including a gnat wing in an inspection channel.

FIG. 19 depicts the position of the gnat wing with respect to the tracks of the operational structures.

FIG. 20 shows the HF signals acquired from a track of the operational structures illustrated in FIG. 19.

FIG. 21 depicts the position of the gnat wing with respect to the tracks of the operational structures.

FIG. 22 demonstrates the HF signals acquired from a series of consecutive tracks of the operational structures illustrated in FIG. 21.

FIG. 23 depicts the position of the gnat wing with respect to the tracks of the operational structures.

FIG. 24 shows a high density compilation of the HF signals acquired from the tracks across the gnat wing.

FIG. 25 shows an objective lens focusing mechanism as used in one embodiment of the present invention.

FIG. 26 illustrates an optical disc assembly containing a reflective hologram.

FIG. 27 illustrates the data and surface organization of a zoned constant linear velocity (ZCLV) format.

FIG. 28 shows an enlarged perspective view of a portion of a section of a ZCLV disc, wherein the portion has a pre-groove area followed by a wobble groove area.

FIG. 29 shows investigational features placed in a section in a ZCLV disc.

FIG. 30 is an example of a forward disc, wherein the operational structures are coated with a semi-reflective layer, and investigational features are held laser-distal to the semi-reflective layer.

FIG. 31 shows a example of a forward disc which permits the laser light to pass through the disc to a top detector.

FIG. 32 depicts a reverse optical disc assembly which includes fluidic channels placed either above or below the operational surface.

FIG. 33 shows another reverse optical disc assembly in which the operational surface has a cut-away area and fluidic channels are placed either above or below the cut-away area.

FIG. 34 illustrates an example of a reverse optical disc assembly which includes channels and an analyte chamber.

FIG. 35 depicts a forward optical disc assembly which includes fluidic channels placed either above or below the operational surface.

FIG. 36 shows another forward optical disc assembly in which the operational surface has a cut-away area and fluidic channels are placed either above or below the cut-away area.

FIG. 37 shows a forward optical disc assembly, wherein channels are contained in a lens layer.

FIG. 38 shows a forward disc with channels placed above or below a cut-away area.

FIG. 39 shows a forward disc assembly having a cut-away area.

FIG. 40 illustrates an exploded perspective of the principle layers in a forward disc assembly according to one embodiment of the present invention.

FIG. 41 shows a design of an operational layer.

FIG. 42 shows a design of an adhesive layer.

DESCRIPTION OF EMBODIMENTS OF THE INVENTION

This invention relates to an optical disc assembly configured to receive an analyte of interest which can be detected by an optical disc reader. The analyte of interest may be a physical specimen, such as a biological, chemical, or biochemical specimen, or a product produced by a biological or chemical reaction carried out in the optical disc assembly. The optical disc reader may be a CD reader or a DVD reader. The optical disc reader may be a standard optical disc reader or an optical disc reader modified therefrom. The optical disc assembly may be designed so that the association of the analyte with the disc assembly does not prevent the optical disc reader from tracking the disc assembly or performing other operational functions.

As used herein, various surfaces in an optical disc assembly can be numbered or named according to the order in which the light beam of the optical disc reader strikes or passes through them upon first occurrence. For example, when a compact disc (CD) is read by a CD reader, the laser beam of the CD reader first enters the disc through a surface of a polycarbonate layer. The polycarbonate layer also is known as the polycarbonate disc or the substrate. This surface is referred to as the first surface or the laser-proximal surface of the polycarbonate layer. The laser beam proceeds through the polycarbonate layer and comes out through another surface of the polycarbonate layer. This latter surface is referred to as the second or the laser-distal surface of the polycarbonate layer. The laser beam proceeds to a reflective layer which is usually made of gold or other reflective material. The reflective layer is laser-distal to the polycarbonate layer. The laser beam is reflected back from the reflective layer, passing through the polycarbonate layer and entering a detector in the CD reader.

When a CD-R disc is read by a CD-R reader, the laser beam of the reader enters the CD-R disc through the first surface of a polycarbonate layer. The laser beam proceeds through the polycarbonate layer and enters into a dye layer which is laid on the tracks embossed or impressed in the laser-distal surface of the polycarbonate layer. The polycarbonate layer is laser-proximal to the dye layer. The back surface of a CD-R disc, upon which labels or markings are laid, is referred to as the back plane. The back plane is the most laser-distal surface in the CD-R disc.

As used herein, "operational structures" or "operational features" in an optical disc assembly refer to optically readable structures which are impressed or encoded in the optical disc assembly and which enable an optical disc reader to track, synchronize, or perform other

customized operational functions. Operational structures may act as phase components or provide interference patterns. Operational structures may have encoded speed information that enables the optical disc reader to rotate the disc assembly at a speed determinable from the speed information. Light returned from or passed over operational structures can be acquired by the optical disc reader to generate operational signals. These operational signals are used by the optical disc reader to track, focus, synchronize, or perform other operational functions.

Operational structures may be imprinted or impressed in a surface of a layer in the disc assembly. Such a layer is referred to as an "operational layer," and such a surface is referred to as an "operational surface." In a typical CD disc, the operational layer is the polycarbonate disc, and the operational surface is the laser-distal surface of the polycarbonate disc. An optical disc assembly may have more than one operational layer or operational surface. Preferred operational structures include, but are not limited to, wobble grooves, pits and lands, dye marks, or any combination thereof.

Operational structures may be encoded in a hologram. Light returned from or transmitted through the hologram can create an image plane within which the encoded operational structures appear to be positioned. The encoded operational structures, as appeared in the image plane of the hologram, preferably are in the form of wobble grooves, tracks of pits and lands, or any other type of operational structures that may be physically impressed in an optical disc's operational layer.

Operational structures, impressed or encoded, may be in a variety of formats. Suitable formats for this invention include, but are not limited to, CD formats, DVD formats, any combination thereof, or other optical disc formats. CD formats include, but are not limited to, CD-ROM, CD-R and CD-RW formats. DVD formats include, but are not limited to, DVD-R, DVD-RW and DVD-RAM formats. As appreciated by one of skill in the art, other CD or DVD formats or other optical disc formats, including those that have been or will be developed in the future, may be used in the present invention.

"Investigational structures" or "investigational features" refers to the structures, features or items that are placed in an optical disc assembly to be examined. An investigational structure or feature may be an analyte which includes a physical specimen, such as a biological or chemical sample, or a product produced by a biological or chemical reaction conducted in the optical disc assembly. An investigational structure or feature may also be part of an analyte. Investigational structures or features usually cannot provide

operational information. Investigational structures or features typically are not imprinted or impressed in the optical disc assembly. They usually are not encoded in a hologram. Preferably, investigational structures or features are replaceably disposed in the optical disc assembly. Investigational structures or features may be chemical, bio-chemical, or biological in nature. They may also be signal or reporter elements such as beads.

Association of investigational structures with an optical disc assembly of the present invention does not prevent the optical disc reader from operating the optical disc assembly. In order to operate an optical disc assembly, the optical disc reader usually needs to (1) accurately focus above the operational surface of the disc assembly, (2) accurately track the operational surface or use some form of radial movement across the disc surface, (3) maintain a form of speed control, (4) maintain proper power control by logical information gathered from the disc assembly, and (5) respond to logic information that may be used to control, for example, the position of the objective assembly, the speed of rotation, or the focusing position of the laser beam.

An analyte that is disposed in the optical disc assembly of the present invention can be read or detected by an optical disc reader. As used herein, an analyte can be read or detected by an optical disc reader if the optical disc reader can generate at least a signal indicative of the presence of the analyte. The present invention also contemplates the use of the optical disc reader to generate signals indicative of other properties of the analyte, such as the concentration or dimension of the analyte.

In accordance with one aspect of the present invention, the optical disc assembly includes at least an operational layer and at least an analyte section. The operational layer contains an operational surface in which operational structures are impressed. The operational structures have encoded operational information which enables the optical disc reader to operate the disc assembly. In particular, the operational structures may have encoded tracking information that allows the disc reader to track the operational structures. The operational structures may also have encoded speed information enabling the disc reader to rotate the disc assembly at a speed determinable from the encoded speed information. Preferably, the operational structures are coated with a reflective layer containing a reflective material, such as metal, aluminum, gold, silver, or silicon. As used herein, a reflective layer can be semi-reflective and semi-transmissive. Light reflected from the reflective layer can be acquired by the disc reader to generate operational signals for focusing, tracking, or

performing other operational functions. The operational layer may be a hologram in which the operational structures are encoded.

Speed information encoded in the operational structures allows an optical disc reader to rotate the optical disc assembly at a determinable speed. Speed information may be encoded in frame synchronization words which allow the optical disc reader to adjust the disc speed to keep a desired data rate. The speed information may also be encoded in a wobble groove. The wobble groove can produce signals useful for regulating the disc speed. In addition, special marks or logic information can be used to provide speed information. In one embodiment, the optical disc reader rotates the optical disc assembly with a constant linear velocity.

The analyte section is configured to receive at least an analyte of interest. The analyte section may be embedded in the disc assembly. It may be positioned between two layers of the disc assembly. It may also be located within a layer in the optical disc assembly. As used herein, a layer in a disc assembly refers to a thickness of material. For instance, a layer may be a substrate disc or a coating of reflective material. A layer may also be an insert which can be assembled into another layer in the disc assembly. A layer may be flat or not flat. A layer may be homogeneous or non-homogenous. The depth of a layer may be uniform or not uniform. A layer may be an assembly of several parts. The analyte section may be the most laser-distal or the most laser proximal structure in the disc assembly. The analyte section may include channels, microfluidic channels, chambers, cavities, or other structures that are designed for the manipulation, creation, or retention of the analyte of interest or the investigational structure. The analyte section may also be referred to as the component layer. An optical disc assembly may have more than one analyte section. The analyte section and the operational layer can be intermixed so long as the optical disc reader can retain control of focusing, tracking, velocity and other operational functions. Analytes or investigational structures can be in the nanometer, micrometer or millimeter range, and can be disposed, modified or created in the analyte section.

Preferably, the optical disc assembly includes a lens layer. The lens layer may be used to focus the laser beam, for instance, on either the operational structures, or the investigational structures. In one embodiment, the operational layer may function as a lens layer. In such a case, the operational structures are embossed in the laser-distal surface of the operational layer. The refractive index of the lens layer can be selected to perform the desired focusing function. The lens layer typically is laser-proximal to the operational or

investigational structures. Preferably, the lens layer includes a material selected from the group consisting of plastic and glass. More preferably, the lens layer consists of plastic, such as polycarbonate or polystyrene. In a highly preferred embodiment, the lens layer consists of polycarbonate. Other examples of material suitable for constructing a lens layer include polymethylacrylic, polyethylene, polypropylene, polyacrylate, polymethyl-methacrylate, polyvinylchloride, polytetrafluoroethylene, polyacetal, polysulfone, celluloseacetate, cellulosenitrate, nitrocellulose, or any mixtures or combinations thereof.

The optical disc assembly of the present invention preferably approximates the dimensions of a unitary disc. For instance, the disc assembly may have a radial diameter between about 110 mm and 130 mm, including the range from 75 mm to 85 mm, and preferably 120 mm. Preferably, the disc assembly has a depth or thickness between about 0.8 mm and 2.4 mm, such as between 1.0 mm and 1.4 mm. More preferably, the disc assembly has a depth or thickness between 1.1 mm and 1.3 mm, including 1.2 mm. In one embodiment, the disc assembly may have a thickness of about 0.6 mm. The disc assembly may be flat or not flat, circular or non-circular. The disc assembly may have a central hole through which the disc assembly can be coupled to a disc reader.

With reference to FIG. 1, there is shown a diagram illustrating one embodiment of the present invention. The optical disc assembly has at least an operational layer **338**, a component layer **336**, and a lens layer **340**. The disc assembly encompasses the focusing range of the laser used by the disc reader. The operational layer **338** contains the operational structures that are used by the disc reader to track the disc assembly. The operational structures may create an interference pattern or other patterns that provide operational functionality to the disc reader. The component layer **336** contains the investigational structures as well as other structures that are related to the manipulation, creation, or retention of the investigational structures. The component layer may include microfluidic channels. The lens layer **340** may focus the laser beam either on the operational structures or on the investigational structures. The component layer and the operational layer may be intermixed or overlapped so long as the disc reader can retain control of the focusing, tracking and speed. The measurement area **342** represents the area which are readable by the disc reader's laser, and the laser's focal point can roam across the measurement area. The measurement area may encompass any of the component layer, the operational layer, the lens layer, or a portion thereof.

Different layers in an optical disc assembly may have different optical properties and can impose different optical effects on the light beam that passes through these layers. These optical effects include, for example, reflection, refraction, transmission, or absorption. FIG. 2 is a simplified example showing the effects of different layers on the passage of a light beam.

The optical disc **102** in FIG. 2 includes three layers of refractive material, **104**, **106** and **108**. The refractive properties of these layers may differ based on their compositions. The different refractive properties create changes in the light beam **110** as the light beam passes through these layers. The layers may be named in order of their first contact with the light beam **110**. The light beam **110** enters through the bottom surface **112** and exits at the top surface **118**. Therefore, layer **104** may be referred to as the most laser-proximal layer, and layer **108** as the most laser-distal layer. Layer **106** is laser-distal to layer **104**, and laser-proximal to layer **108**.

The light beam **110** enters layer **104** at surface **112**. The light beam is bent and slowed because of the refractive property of layer **104**. The light beam exits layer **104** at surface **114**, and then enters layer **106** which has a different refractive property, therefore further altering the angle and speed of the light beam. As the light beam exits layer **106**, it enters layer **108** at surface **116** with a further changed angle and speed. The light beam exits layer **108** at surface **118**. Surface **112** is laser-proximal to surface **114** which is laser-proximal to surface **116**. Surface **118** is the most laser-distal surface in the optical stack **102**.

In one embodiment, the optical disc assembly is designed based on a modification of an industry standard design, such as standard CD (including CD-R and CD-RW) or a standard DVD (including DVD-RAM, DVD-R and DVD-RW). The following description is based on modifications of a standard CD-R disc. Similar modifications can be applied to other optical discs, such as CD-RW or DVD discs, as appreciated by one of ordinary skill in the art.

A normal CD-R disc contains a wobble groove utilized by the CD-R drive to spin and track the disc. A similar principal applies to a DVD-type disc. A standard CD-R disc has a polycarbonate operational layer having a depth of about 1.2 mm. The polycarbonate operational layer has at least a wobble groove embossed in the laser-distal surface of the layer. The depth of the wobble groove in a standard CD-R is approximately from 165 nanometers to 230 nanometers. A typical wobble groove is filled with dye. Above the dye layer is a reflective layer which contains gold or other reflective material such as silver. The reflective layer can reflect the laser beam of the disc drive back to a detector in the disc drive.

The laser beam can be focused on the reflective layer. The laser's focus may be adjusted by a focusing servo. The wobble groove functions like a diffraction grating, and is capable of creating a pattern in the reflected laser light. The pattern in the reflected laser light is used by the disc drive to spin and track the disc. In a standard DVD disc, the wobble groove depth can be 50 nanometers.

FIG. 3 exemplifies a CD-R disc with an industry standard design. The disc has an operational layer **120** which is usually made of polycarbonate, a dye layer **122** which contains CD recordable light sensitive dye, and a reflective layer **124** which contains gold, silver or other material that is suitable for reflecting the laser beam **128** back to the detector of the disc drive. The operational layer 120 is capable of focusing the laser beam **128** on the reflective layer **124**. As used herein, a layer in an optical disc is capable of focusing a reading beam of an optical disc reader on an object if the reading beam, which is directed to the object, can pass through the layer and become focused on the object while the optical disc reader is operating the optical disc. Preferably, the refractive index of the layer is significantly greater than the refractive index of air, as appreciated by one of skill in the art. For instance, the refractive index of the layer may be 1.55. Other layer or layers may also exist in the optical path of the reading beam to help the reading beam become focused on the object. The wobble groove **126** is shown in FIG. 3.

FIG. 4 demonstrates the geometry of a wobbled groove in a CD-R. As with other figures used herein, FIG. 4 is not drawn to scale. The wobble groove is usually embossed into the laser-distal surface of the operational layer in a CD-R. FIG. 4 shows two wobbled grooves. Measurement A, **132**, represents the distance between two adjacent wobble grooves. Measurement B, **134**, denotes the width of the top of the wobble groove. Measurement C, **136**, represents the width of the bottom of the wobble groove. Measurement D, **138**, shows the depth of the groove. The angle E, **140**, between the side-wall **142** and the bottom of the wobble groove has an important effect on light that encounters the wobbled groove. The geometry of the wobble groove in a CD-R disc has a significant effect on the performance of the CD-R disc in a high speed writer.

An optical disc spins in a disc reader clockwise when looking down on the disc. From the viewpoint of the reader's laser (looking up), however, the disc is spinning counter-clockwise. FIG. 5 demonstrates a common arrangement of an optical disc in a disc drive. The same arrangement can be employed in the present invention. The laser beam **146** is directed to the optical disc **144** from below. The optical disc **144** spins in a

counter-clockwise direction **148** as seen from below the disc. From above the disc, however, the disc **144** spins in a clockwise direction.

The optical disc of the present invention may be designed based on modifications of a standard CD-R disc. The standard CD-R disc is a "forward" disc, in which the operational structure is positioned at the laser-distal surface of the operational layer. Whereas the operational structure of a forward disc is a wobble groove, the disc is also referred to as a "forward wobble" disc. A forward wobble disc has its wobble groove positioned on the second surface or the laser distal surface of the operational layer.

FIG. 6 illustrates a forward disc **150**. Laser beam **152** enters the operational layer **158** at its first or laser-proximal surface **154**. The light is bent according to the refractive property of layer **158**. The focus of the laser beam **152** encompasses the bottom of wobble groove **160**. Wobble groove **160** is embossed in the second or laser-distal surface **156** of layer **158**. Reference numeral **159** denotes a land of the wobble groove.

FIGs. 7 and 8 illustrate the forward discs that may be employed in the present invention. The forward optical disc assembly **224** in FIG. 7 includes an operational layer **226** which has wobble grooves in its laser-distal surface. The wobble grooves are coated with a reflective layer **228** containing reflective material, such as gold. The reflective layer **228** may be semi-reflective. The operational surface has a cutaway area at location **229** which allows laser light **230** to pass through the wobble grooves and reach another reflective layer **232**. The reflective layer **232**, which contains reflective material, can be deposited on a top cover layer **234** which can provide a stable surface for the reflective layer **232**. Assembly **224** also has an analyte section **236** which is configured to receive analytes of interest. The tracking of the disc is performed by the laser beam **230** when it encounters the reflective layer **228** that covers the wobble grooves. The size and configuration of the cut-away portion **229** is calculated to allow the laser to resume tracking before control of the disc is lost by the disc drive's tracking mechanism. The reflective layer **232** permits the laser beam to return to a detector in the disc reader after the laser beam passes through the cut-away portion **229** to the analyte section **236**.

As used herein, a "cut-away" area refers to an area in the operational surface, wherein the area either lacks operational structures or the operational structures in the area are changed in certain ways. The operational structures in a cut-away area may be deprived of reflective coatings, or be coated with a reflective material having a different reflectivity than the reflective material coated on other regions in the operational surface. In a preferred

embodiment, one surface of the analyte section is adjacent to a cut-away area, or includes a cut-away area.

FIG. 8 shows another forward optical disc which includes an investigational structure **354**. The operational layer **344** contains the operational structures which are embossed at its laser-distal surface and coated with a reflective layer **350**. The operational layer serves as a lens layer and can focus the laser beam **352** on the operational structures. The analyte section **346** is configured to hold an investigational structure **354**, which is within the focal zone **356** of the optical disc reader's laser. The laser beam **352** may pass through a cut-away area **348** and be focused on the investigational structure **354**. The cut-away area lacks the reflective coating. The disc assembly has a second reflective layer **360** which is laser-distal to the operational structures and capable of reflecting laser light. The cover **358** is laser-distal to the second reflective layer. The analyte section **346** contains the cut-away area **348** upon which the investigational structure **354** is positioned.

As used herein, a laser's focal zone refers to the range of distance within which the laser's focal point may be positioned. In a standard CD drive, the laser's focal zone is about 25 to 26 micrometers. Thus, the laser's focal point can move above and below a trackable surface in a range of about 12.5 to 13 micrometers. Some variations (about ± 2 micrometers) are allowed for the movement. Accordingly, in a preferred embodiment, the analyte section is capable of positioning an analyte at least within about 15 micrometers from the trackable surface in order for the laser reading beam of the optical disc reader to be focused on the analyte. When a hologram is used to encode operational structures, the analyte preferably is located within about 15 micrometers from the image plane of the hologram. In one embodiment, a surface of the analyte section is located within about 15 micrometers from the trackable surface or the image plane of the hologram. The surface of the analyte section may also be capable of receiving the analyte. The surface of the analyte section may be part of a larger surface of the analyte section. The 15 micrometers limitation may be modified in a modified optical disc reader.

In a preferred embodiment, the optical disc assembly employs a spiral wobble groove to provide operational signals. As used herein, a spiral wobble groove can be considered as a series of wobble grooves connected consecutively to form a spiral track. The depth of the wobble groove is preferably from 50 to 100 nanometers, including 65 nanometers, 70 nanometers, 73 nanometers and 100 nanometers. More preferably, the depth of the wobble groove is approximately 1/8 of the effective wavelength of the laser light in the layer which is

immediately laser-proximal to the operational surface. Such a depth may provide a strong tracking signal. The groove may also have a depth approximately equal to any odd multiple of 1/8th of the wavelength, such as 3/8ths or 5/8ths. The depth of the groove may remain substantially constant along the wobble groove. The periodic perturbation of the wobble provides the information for tracking. In one embodiment, the spiral groove has a track pitch of approximately 1.6 microns.

Preferably, no dye is laid down in the wobble groove, or the dye is laid down in discrete patterns so as to facilitate drive control during the examination of investigational features. The present invention discovers that a conventional CD-R wobble groove without dye is readable by a standard optical disc reader. The groove can be coated with a layer of reflective material, such as gold, or semi-reflective material. The reflective layer preferably is positioned sufficiently close to the groove structure so as to provide adequate reflection when the laser light focuses on the groove structure. In addition, the pitch and angle of the groove walls can be selected to facilitate the detection of investigational features which are placed on or between various surfaces or layers in the disc.

In accordance with one aspect of the present invention, the optical disc assembly is a "reverse" disc. The operational structures in a reverse disc are imprinted or impressed in the laser-proximal surface of the operational layer. When the operational structure is a wobble groove, the reverse disc may also be referred to as a "reverse wobble" disc. A reverse wobble disc has the wobble groove impressed in the laser proximal surface of the operational layer. A standard CD-R disc has the wobble groove impressed in the laser-distal surface of the operational layer.

FIG. 9 depicts a reverse wobble disc assembly **162**. The reverse wobble disc assembly **162** includes an operational layer **164** and a cover **166**. The operational layer **164** is further shown in an enlarged view **168**. Cover **170** represents the enlarged view of cover **166**. Cover **170** provides the most laser-proximal layer in the disc assembly. The laser beam **172** enters cover **170** at its laser-proximal surface **174**. The laser beam at surface **174** is bent due to the refractive property of cover **170**. The laser exits the cover and is focused on the wobble groove **176** which is embossed in the laser-proximal surface **178** of the operational layer **168**. The laser may or may not pass through the wobble groove to reach other layers.

FIG. 10 shows a reverse wobble disc containing an investigational structure. The cover **362** acts as a lens to focus the laser beam **364** onto the operational structures. The laser beam **364** may also be focused on the investigational structure **366**, depending the reflectivity

of the investigational structure **366**. The investigational structure **366** is held in the analyte section **372** which is between the operational layer **370** and the cover layer **362**. The analyte section **372** lies within the laser's focal zone **368** which also encompasses the operational surface. The operational structures are covered by a reflective layer **374**.

The process for manufacturing a reverse wobble disc is different from the process for making an industry standard forward wobble disc. FIGs. 11 and 12 demonstrate the difference between making a reverse wobble disc and making a forward wobble disc. The process for making a normal, forward wobble CD-R is shown at **188**, whereas the process for making a reverse wobble disc is shown at **190**. In both cases, a master **192** is made. A father stamper **194** is made from master **192**, as appreciated by one of skill in the art. A mother **196** is made from the father stamper **194**. The image embossed in the mother **196** is thus a duplicate of the original master **192**. To make a forward wobble disc, a son stamper **198** is further made from the mother **196**. The son stamper **198** has an image identical to that of the father stamper **194**. A forward wobble disc, as shown in FIG. 12, is then made from the son stamper **198**. In contrast, a reverse wobble disc **202** is made from the mother stamper.

FIG. 12 further illustrates the difference between manufacturing a forward wobble disc and manufacturing a reverse wobble disc. The son stamper **198'** is identical to the son stamper **198** in FIG. 11. The son stamper **198'** is used to create a wobble groove on the laser-distal surface **208** of the substrate layer **204**, therefore creating a forward wobble disc. Surface **208** may be coated with a dye layer **210** which is further layered with a reflective coating **212**. Preferably, the surface **208** is directly coated with the reflective coating **212** without the dye layer **210**. The laser beam of the disc reader can travel through the most laser-proximal surface **206** and then the operational layer **204** to reach the surface **208**. The surface **208** is the operational surface.

In comparison, the reverse wobble discs **214** and **202'** are made from the mother stamper. The wobble groove in the reverse wobble disc **214** is positioned at the first or laser-proximal surface of the operational layer **216**. Surface **218** is the second or laser-distal surface of the operational layer **216**. The cover **222** is capable of focusing the laser beam on the wobble groove. To facilitate the reading of the wobble groove, a reflective layer **220** is deposited on the first surface of layer **216**. The first surface of layer **216** is the operational surface. As viewed from the optical pick of the optical disc reader, the operational surface of the reverse wobble disc **214** appears to have the same image as the operational surface **208** of the forward wobble disc.

A reverse wobble disc can be manufactured so that the spiral of the wobble groove moves from the inner diameter of the disc to the outer diameter of the disc when the disc is spun counter-clockwise as viewed from the laser. This configuration is the same as used by a conventional forward wobble disc.

In another embodiment, a reverse wobble disc can be prepared using a process similar to process **190** in FIG. 11. However, the wobble groove in the master disc has a reverse image of the wobble groove in the master disc **192**. The reverse wobble disc thus prepared has the wobble groove impressed at the laser-proximal surface of its operational layer. A standard CD-R or CD-RW reader can track both the reverse wobble disc of this embodiment and the reverse wobble disc manufactured using the master disc **192**. The disc tracking is dependent upon the frequency of the wobble. Likewise, a forward wobble disc can be created using process **188** but with a master disc having a reverse image of the master disc **192**.

FIG. 13 demonstrates a reverse disc according to one embodiment of the present invention. The reverse disc **240** includes an operational layer **242** which contains a wobble groove **250** at its laser-proximal surface. The wobble groove **250** is coated with a reflective layer **248** which contains reflective material, such as gold. The laser beam **246** can be focused by the cover **244** upon the wobble grove **250** or upon the reflective layer **248**. The assembly **240** permits investigational structures to be placed in the analyte section **252** and to be examined by the laser beam **246**.

For more information about optical discs in which operational structures are positioned in the laser-proximal surface of the operational layer, see U.S. Patent Application Serial No. 09/421,870, entitled "Trackable Optical Discs With Concurrently Readable Analyte Material," which is incorporated herein by reference.

In accordance with one aspect of the present invention, various types of data or information can be digitally encoded in the disc assembly. These data or information may be encoded in accordance with industry standards, such as CD or DVD standards, or standards modified therefrom. These encoded data or information may control or facilitate an optical disc reader to track the disc assembly or detect investigational structures that are disposed in the disc assembly.

Investigational structures that are disposed in an optical disc assembly can be read or detected using an optical disc reader, such as a CD reader or a DVD reader. As used herein, CD readers include, but are not limited to, CD-ROM readers, CD Recordable (CD-R)

readers, CD-Rewriteable (CD-RW) readers, or any reader capable of reading CD-format discs. Industry standard CD readers may be used in the present invention. Preferably, a standard CD-RW reader or a modification thereof is used in the present invention. As used herein, DVD readers include, but are not limited to, DVD-R readers, DVD-RAM readers, DVD-RW readers, or any reader that can read DVD-format discs. Industry standard DVD readers may be used. As appreciated by one of skill in the art, other CD readers, DVD readers or optical disc readers, including those that have been or will be developed in the future, may be used in the present invention. An optical disc reader may read both CD and DVD discs.

Signals indicative of the presence or other properties of an investigational structure can be generated by an optical disc reader. The disc reader directs a reading beam of electromagnetic radiation, typically a laser beam, to the optical disc assembly in which the investigational structure is disposed. The disc reader can scan the beam over the area in which the investigational structure is held. The scanning beam can be either reflected from or transmitted through the disc assembly. The reflected or transmitted radiation may be acquired by a detector in the disc reader. Radiation thus acquired can be used to produce signals indicative of the presence or other properties of the investigational structure. Different types of lasers with different wavelengths may be used in the present invention. Whereas a standard optical disc reader is used, the disc reader may be connected to circuitry for processing the signals indicative of the presence or other properties of the investigational structure.

Radiation acquired by the detector of the optical disc reader can also be used to generate operational signals, such as focusing servo signals, tracking servo signals, synchronization signals, power control signals, and logic signals. The focusing servo signals can be generated from at least three focusing techniques: critical angle focusing, knife edge focusing and preferably, astigmatic focusing. Tracking servo signals can be generated from at least four types of tracking techniques: one beam-push-pull tracking, three beam outrigger tracking, differential phase detection tracking, and one beam high frequency wobble tracking. Synchronization signals may be generated from at least three different methods: bit clock synchronization or bit pattern synchronization, zoned clocking method, and wobbling groove synchronization. Logic signals can be produced from various optical disc formats. Logic signals can be used to perform position sensing, power control, radial and tangential location, layer sensing, density detection, or other functions.

Preferably, the optical pickup of a standard CD reader is used to both track the optical disc assembly and detect the investigational structure disposed therein. FIG. 14 illustrates an example of the optical pickup of a standard CD reader. The optical pickup **254** contains a laser source **260**, which typically is a laser diode. The laser source emits a laser beam **262**. The laser beam is collimated by a collimator lens **264**. The collimated beam is then directed toward the optical disc through a polarization beam splitter **266**. The objective lens **268** focuses the laser beam onto a small spot on a surface in the optical disc. In FIG. 14, the surface is the operational surface of a CD-type optical disc, which contains pits and lands **256**. The surface preferably is coated with a reflective layer, so that the laser beam can be reflected therefrom and then directed by the objective lens **268**, the mirror **270** and the quarter wave plate **272** to the beam splitter **266**. As the light is now polarized in a different direction as compared to the source polarization, it can be directed by the beam splitter towards a photodiode detector **274**. A cylindrical lens **276** may serve as an astigmatic element to introduce astigmatism in the reflected laser beam for the purpose of focusing.

In a preferred embodiment, the laser beam is split into three beams, consisting of a main beam and two tracking beams, and the detector is a quad detector. FIG. 15 shows a quad detector **278**, which includes a central quad detector **280** flanked by two additional sensor elements E **281** and F **282**. The main beam is centered on a track defined by pits in a CD-ROM disc. The tracking beams fall on either side of the track. By design, the three beams are reflected from the optical disc and then directed to the quad detector **278** such that the main beam falls on the central quad detector **280**, which includes sensor elements A, B, C, and D, while the tracking beams fall on the sensor elements E **281** and F **282**. The sum of the signals from the central quad detector, i.e. A + B + C + D, provides the radio frequency (RF) signal **284**, also referred to as the high frequency (HF) or the quad-sum signal. A tracking error signal (TE signal) **288** may be obtained from the difference between E and F. Because astigmatism is introduced by the cylindrical lens astigmatic element, a focus error signal (FE signal) **286** may be obtained from the difference between A+C and B+D signals. Other combinations of the signals from A through F may be obtainable, as appreciated by one of ordinary skill in the art. These combinations of signals may be used to track the disc and read the investigational structure disposed in the disc. A quad detector and a similar optical design may be employed in a DVD reader.

In one embodiment, the quad-sum signal is used for extracting information indicative of the presence or other properties of the investigational structure disposed in the disc

assembly. Preferably, the disc assembly contains a wobble groove which is trackable by a disc reader. Suitable disc readers include CD-R readers, CD-RW readers or DVD readers. The use of the wobble groove enables the segregation of the tracking signal from the quad sum signal, permitting the quad sum signal to be used to detect signals from investigational structures. If the investigational structure is small enough, an electrical deflection may be detected in the quad-sum signal, while no such a deflection, or a comparatively smaller electrical impulse, will be noted in the tracking signal or the focusing servo signal.

A large investigational feature may also be detected by using the quad-sum signal without losing the tracking of the disc assembly. In such a case, a forward disc, such as that shown in FIGs. 31 and 37, is preferably used. The ability of an operational structure, such as the wobble groove, to permit both disc tracking and analyte detection is herein referred to as segregation of tracking from investigational structures.

The signals produced from a wobble groove can be used by the disc reader to maintain a constant linear scanning velocity at all points on the disc. This allows determination of the dimensional information of the investigational structure that is placed in the disc. Therefore, wobble groove is a preferred operational structure employed in this invention.

Although the above-described embodiment uses the quad-sum signal and the wobble groove, signals other than the quad-sum signal and operational structures other than the wobble groove may be used for the detection of investigational structures. For instance, the focus error signal obtained by the critical angle method, as described in U.S. Patent No. 5,629,514, may be used. The Foucault and astigmatism methods, as described in "The Compact Disc Handbook," by Pohlmann, A-R Editions, Inc. (1992), may also be employed. In addition, the tracking error signals obtained using the single beam push-pull method as described in "The Compact Disc Handbook," by Pohlmann, A-R Editions, Inc. (1992), the differential phase method as described in U.S. Patent No. 5,130,963, or the single beam high frequency wobble method can be used for the present invention. The block error rate information, such as those used by a CD reader to reduce the effect of scratches on a CD surface, or the movement of the focusing servo may be used.

For more optical pickup designs and operational signals that may be used in the present invention, see "Compact Disc Technology," by Nakajima and Ogawa, IOS Press, Inc. (1992); "The Compact Disc Handbook," by Pohlmann, A-R Editions, Inc. (1992); "Digital Audio and Compact Disc Technology," by Baert et al. (eds.), Books Britain (1995);

"CD-Rom Professional's CD-Recordable Handbook: The Complete Guide to Practical Desktop CD," Starrett et al. (eds.), ISBN:0910965188 (1996). All these references are incorporated herein in their entirety by reference.

U.S. Provisional Application Serial Nos. 60/270,095 and 60/292,108 further detail how to extract or process signals indicative of the presence of an investigational structure disposed in an optical disc assembly. Both applications are incorporated herein by reference.

FIG. 16 and FIG. 17 illustrate a measurement of investigational structures using an optical disc assembly according to one embodiment of the present invention. The analyte section is laser-proximal to the operational layer, and is positioned between the operational surface and a lens layer. FIG. 16 depicts the position of the investigational structures **800** with respect to the tracks **802, 804, 806** and **808**. The investigational structures **800** are held in the analyte section and positioned on the operational surface. The investigational structures **800** are 2.8 micrometer magnetic beads. Tracks **802, 804, 806** and **808** are embossed in the operational surface. Each track preferably is in the form of a wobble groove.

FIG. 17 shows the HF signals **802', 804', 806'** and **808'** that are acquired along the tracks **802, 804, 806** and **808**, respectively. The HF signals shown in FIG. 17 have been digitalized and buffered. The HF signals **802', 804', 806'** and **808'** demonstrate the existence as well as the approximate dimension of the investigational structures **800**.

FIGs. 18 through 24 illustrate the measurement of a gnat wing disposed in an optical disc assembly. FIG. 18 is a cross-sectional view taken perpendicular to a radius of the optical disc assembly. In FIG. 18, the optical disc assembly includes an operational layer **814**, a first reflective layer **816**, a second reflective layer **810** and a cover **812**. The analyte section **826** is located between the second reflective layer **810** and the operational layer **814**. The operational surface **818** is the laser-distal surface of the operational layer **814**. The operational surface **818** is embossed with tracks of operational structures, preferably, wobble grooves. The operational surface **818** is covered by the reflective layer **816**. The operational surface has a cut-away area **824** which may lack the reflective coating **816**. The gnat wing **822** is located in the analyte section **826** and positioned upon the cut-away area **824**. The laser beam **820** can pass through the operational layer **814**, the cut-away area **824** and the gnat wing **822**, and then be reflected by the reflective layer **810**.

FIG. 19 diagrammatically shows the position of the gnat wing **822** relative to the tracks embossed in the operational surface. **T1** denotes a track upon which the gnat wing is

positioned. FIG. 20 shows the HF signal acquired along the track **T1**. The HF signal has been digitalized and buffered.

In FIG. 19, the Y-axis, labeled with "TRACKS," represents the number of tracks along a radius of the disc assembly. The X-axis, labeled with "TIME (SAMPLES)," represents the number of sampling along a track. For instance, the gnat wing can be sampled by the disc reader along the track **T1** at least about 800 times (from sample number 1550 to sample number 2350).

FIG. 21 shows the position of the gnat wing **822** relative to the tracks **T2** and **T3**. FIG. 22 demonstrates the HF signals for a series of consecutive tracks between **T2** and **T3**.

FIG. 24 is a high density compilation of the HF signals for the tracks across the gnat wing. The image of the gnat wing appears in FIG. 24. FIG. 23 shows the position of the gnat wing **822** relative to the tracks.

In accordance with another aspect of the present invention, the optical disc reader includes an objective lens focusing mechanism which is capable of focusing the disc reader's laser onto different surfaces in the disc assembly. In one embodiment, the focusing servo **290** shown in FIG. 25 includes a coil and magnet casing surrounding the objective lens. The objective lens **292** directs the laser **294** onto the surface **296** of the disc. Then the laser light travels through a lens layer, and focuses onto the operational surface **298**. The operational surface contains operational structures, such as wobble grooves, or pits and lands. The objective lens is held by a brace **302** which is part of the moving coil controlled by the magnet **306**. The magnet **306** is activated by the signal generated when the laser light **294** returns from the disc to the detector of the disc reader. The moving coil **304** and the objective lens can move within the range **308**. The range **308** controls the range of the laser's focal zone.

The focusing servo of the present invention may move the laser's focal point across the laser's focal zone. The laser's focal point may represent the point where the focusing servo finds a maximal amount of light returned to the disc reader's detector. The location of the laser's focal point therefore may be affected by the reflective properties and other optical properties of various elements contained in the optical disc assembly. For instance, where the optical disc assembly is based on the modification of a conventional CD-R, the focal point may be at the reflective layer which contains gold or other reflective material.

More than one reflective layer, including semi-reflective layers, may be constructed within the laser's focal zone. The reflective layers in the focal zone can create a level of

signals, the voltage of which is affected by the position of the focal point and the reflectivity of the reflective layers. The focusing servo may be able to search for a focal point from which the light returned to the detector is maximal.

In a preferred embodiment, the operational structures in the optical disc assembly are designed to provide an improved detection for the investigational structures. The investigational structures may be cells, microorganisms or any other biological, biochemical, or chemical specimens. In one instance, the pits, lands, or wobble grooves are reconfigured to enhance tangential resolution. In another case, the pits are shortened or the wobble is changed to provide a lower scanning speed in order to increase the radial resolution. In yet another instance, the lens layer is changed to PMMA or other material to improve optical response. The lens layer may also be made thicker or thinner to make the focal spot smaller or larger, therefore providing higher or lower energy distributions on the detector. The operational structures may be interleaved to provide dynamic responses for enhancing imaging.

The present invention contemplates a variety of embodiments of the optical disc assembly. For instance, the optical disc can be a forward disc or a reverse disc. The optical disc can have more than two reflective layers. The operational structures can include pits, lands, grooves, wobble grooves, dye marks, chevron marks, or any combination thereof. The operational structures may act as phase components or create interference patterns that provide tracking and synchronization information to the disc drive. The operational structures can be in a CD format (including a CD-R and CD-RW format), a DVD format (including a DVD-R format, a DVD-RW format and a DVD-RAM format), any combination thereof, or any other optical disc format. The operational structures can be physically imprinted in a surface of the operational layer, or encoded in a hologram. A custom format for operational structures may also be used, and the disc assembly is read by a custom decoding device. Different surfaces in the optical disc assembly can be metalized or coated with materials with a variety of reflective properties. The coatings may be reflective, semi-reflective, transmissive, semi-transmissive, or anti-reflective. The materials used in the various layers may be dielectric or non-dielectric. Moreover, the operational layer may be created using different processes, such as molding, electroforming, or web manufacturing.

The analyte section of the optical disc assembly can be configured to receive an insert which holds the analyte of interest. The insert can be glass or plastic. The insert may be a sample slide regularly used for examining biological, biochemical, or chemical samples. The

insert may be replaceable or integrated with the disc assembly. The insert may hold chemical, biological or other physical specimens. Chemical or biological reactions, including molecule-molecule bindings or enzymatic reactions, can be performed either on the insert or in the analyte section. Products of these chemical or biological reactions may generate optical effects on the incident laser light which can in turn be detected by the disc reader. The insert may function as a cover layer or a lens layer.

The analyte section may include investigational structures which are replaceable or integrated with the disc assembly. The investigational structures may contain light absorbing, light reflecting materials, or anti-reflective materials, so that they may be detectable by the optical pickup of the disc reader. The focusing servo may search for the focal point with maximal return light. Such a focal point may depend on the reflectivity of the investigational structures.

The analyte section or any other layer in the disc assembly may contain channels or chambers, including microfluidic channels, through which analytes, investigational features or reactive components may enter or exit the analyte section. These channels or chambers may also be used to hold the analytes or investigational features for investigation.

The optical disc assembly of the present invention preferably includes a lens layer. The thickness of the lens layer may be about 1.1 mm to 1.3 mm, including about 1.2 mm. Such a lens layer may be used in a disc assembly that is modified from a CD-type disc. The thickness of the lens layer may also be about 0.6 mm, and can be used in a disc assembly modified from a DVD-type disc. The refractive index of the lens layer preferably is selected so that the laser of the disc reader can be focused in a desired manner. The lens layer may be made from a variety of materials, including glass, plastic, PMMA, polystyrene, polycarbonate, or dyed material. The lens layer may be flat or non-flat. The lens layer may be homogeneous or non-homogenous. The lens layer may be incorporated into the operational layer. The lens layer may contain at least part of the analyte section.

The lens layer may also contain molded features, such as cavities, channels or waveguides. The lens layer may function as a cover to protect the operational layer or other layers of the disc assembly. The lens layer may provide physical support for other layers in the disc or for the investigational structures or the analytes that are associated with the disc. The lens layer may be either laser-proximal or laser-distal to a reflective layer or a semi-reflective layer.

In a preferred embodiment, the operational layer includes or consists of a hologram. The operational structures are encoded in the hologram. Preferably, the hologram is a reflective hologram, and is protected by a transparent protective coating located laser-proximal to the hologram. FIG. 26 shows an optical disc assembly containing a reflective hologram **512** which is protected by a transparent protective coating **514**. The hologram encodes the operational structures, such as wobble grooves, that are required by the operation of the optical disc reader. When a laser beam **516** is reflected from the hologram physical plane **512**, it appears as though the encoded operational structures, such as wobble grooves in a correct orientation, are present at the hologram image plane **518**. The hologram image plane **518** can be located substantially confocal with the investigational structure **520**. The investigational structure **520** may be positioned on the laser-distal surface **522** of the lens layer **524**.

The laser beam may be focused on the image plane **518** which is shared by both the investigational structure **520** and the encoded operational structures. Therefore, light from the image plane **518** may enable the disc reader to generate both the operational signals, such as the signals used for disc tracking, and the investigational signals that are indicative of the presence of the investigational structure. This feature allows the optical disc reader to track the disc and detect the investigational structure concurrently and discriminably. The larger the illuminating laser spot **526** on the hologram, the better the image of the operational structures as appeared in the image plane **518**. Therefore, the laser preferably is not tightly focused on the hologram physical plane. Typically, a portion of the hologram physical surface may be sufficient to generate the entirety of the image of the operational structures that are interferometrically encoded in the hologram.

The hologram image plane may be positioned not concurrently with the investigational structure, provided that the operational structures, such as the wobble groove, can be concurrently detectable with the investigational structure. The image plane of the hologram may be either laser-proximal or laser-distal to the investigational structure. In addition, the hologram image plane may be either laser-proximal or laser-distal to the hologram's physical plane.

Preferably, the hologram is replaceable or reversibly attachable to the disc assembly. This permits the hologram to be mass-produced using a high-speed holographic printing process. This also permits the re-use of the hologram or other parts of the disc assembly.

In another preferred embodiment, the operational structures in the optical disc assembly are configured and organized in accordance with the "zoned constant linear velocity" (ZCLV) format. The ZCLV format is detailed in various industry standards, including the DVD-RAM specification. FIG. 27 schematically illustrates the ZCLV format in a circular disc. The ZCLV disc in FIG. 27 is divided into multiple zones **490** across the range **492**. Although only five zones are shown in FIG. 27, actual ZCLV format discs may have different numbers of zones. For instance, the DVD-RAM ZCLV format allows 24 zones.

Each of the zones **490** is divided into multiple sectors **494**. Inner zones have fewer sectors than outer zones, because the radii of inner zones are less than the radii of outer zones. The optical disc reader can scan each zone at a constant rate. In addition, the optical disc reader can rotate the ZCLV disc faster when it scans the inner zones than when it scans the outer zone. Therefore, the optical disc reader may maintain a substantially constant scanning rate for all the zones in a ZCLV disc.

FIG. 28 shows an enlarged perspective view of a portion of one of the sectors of the ZCLV disc. The operational structures consist of multiple tracks **498** which are arranged radially within the sector. Each track has header information embossed in a "pre-groove" area **500**. The pre-groove area is followed by a "wobbled land and groove" area **504** which contains the wobble groove **498** and the wobbled land **502**. Operational structures in a ZCLV format may be holographically encoded in a hologram.

FIG. 29 shows a ZCLV-formatted optical disc assembly associated with analytes or investigational structures **510**. Analytes or investigational structures **510** may be deposited within the "wobbled land and groove" area **508**. The embossed header information in the pre-groove area **506** can be used to store information for identifying or controlling a desired measurement of the analytes or investigational structures **510**. Accordingly, different sectors in the same ZCLV disc may be used to perform different measurements or assays.

In one embodiment, the zones in a ZCLV formatted disc can be mastered in such a way as to provide either a highly reflective surface, a partly reflective surface, or a non-reflective surface. In each case, the pre-header information can provide tracking and location information. The pre-header information may also provide identification information for the nature of the zone. In addition, the pre-header information may encode information relating to the software or firmware that is applied to the zone. The characteristics of the

investigational structures (such as their reflectivity, absorptivity, or transmissivity) can be determined by the disc laser as it scans over each zone.

In a preferred embodiment, the optical disc assembly includes a semi-reflective layer which is both transmissive and reflective to the laser light. The semi-reflective layer is usually a thin layer of reflective or semi-reflective material, such as silicon, tellurium, selenium, bismuth, aluminum, silver, copper or other suitable metals or alloys. The thickness of the layer may range from 10 nm to 100 nm. The reflectivity of the semi-reflective layer may range from about 18% to 30%. The reflectivity may also range from about 30% to 40%. The semi-reflective layer may be used to coat operational structures. Whereas the reflectivity of the semi-reflective layer is low, for instance, below about 30%, a CD-RW reader or a DVD reader preferably is used to read the operational structures that are coated with the semi-reflective layer.

FIG. 30 illustrates a forward optical disc assembly which includes a semi-transmissive, semi-reflective layer. The semi-transmissive, semi-reflective layer **530** is placed on the operational structures which are embossed in the laser-distal surface of the operational layer **528**. Reference numeral **534** shows an operational structure coated with the layer **530**. The reflectivity of the layer **530** can return sufficient light to render the operational structures detectable by the disc reader. The laser beam **532** can also pass through the layer **530** to enter the analyte section **531** which is configured to hold the analyte **538**. The analyte section **533** and the analyte **538** are within the laser's focal zone **536**. The laser beam **532** can be reflected back from another reflective layer **533** which is laser-distal to the semi-transmissive, semi-reflective layer **530**. This latter reflected light may carry signals indicative of the presence of the analyte. The laser's focus is able to roam within the focal zone **536**.

FIG. 31 illustrates a forward transmissive pass-through disc assembly which permits the laser light **540** to pass through the top refractive layer **542** to a top detector. The laser **540** is focused by the lens layer **544**, which is also the operational layer. The operational features are coated with a partly reflective and partly transmissive layer **548**. Reference numeral **546** shows a coated operational feature. The analyte **550** is placed in the analyte section **552** which is situated between the lens layer **544** and the top refractive layer **542**. Samples including solutions may be directed to and expelled from the analyte section **552** through channels or other means. The laser's focus, driven by the laser's focusing servo, can roam

within the focal zone **554**. The coated operational features and the analyte **550** are both placed within the focal zone and can be detected concurrently and discriminably.

In accordance with another aspect of the present invention, the optical disc assembly may contain channels or chambers capable of transporting analytes, reactive components or mediums to and from the analyte section. Analytes and other components can be mixed within these channels or chambers. Preferably, the analyte section also contains at least one chamber or channel which is capable of holding the analytes for investigation. More preferably, the operational surface contains a cut-away area which may be either laser-proximal or laser-distal to the analyte section and which may be adjacent to the analyte section. Most preferably, the analyte section includes a cut-away area as one surface.

FIG. 32 demonstrates a reverse disc assembly **578** including fluidic channels. The lens layer **570** is laser-proximal to the operational layer **572**. The operational structures are embossed in the laser-proximal surface of the operational layer **572**. The plane **574** depicts the plane upon which the operational surface and the operational structures are located. The operational layer **572** contains channels **576** through which analytes or investigational structures can enter or exit the analyte section. The analyte section includes the channel **582** which can be located either laser-proximal or laser-distal to the operational surface. The arrows associated with **576** and **582** indicate the direction of fluidic flow in the channels. The channel **582** and the operational surface are located within the focal zone **584**.

FIG. 33 shows another reverse optical disc assembly **580** in which the analyte section, which includes channel **588**, is either laser-proximal or laser-distal to a cut-away area. The operational surface is position on the plane **574'**. The cut-away area is in the operational surface which is the laser-proximal surface of the operational layer **572'**. The cut-away area preferably lacks operational structures or reflective coatings. Channels **576'** direct the fluidic flow to and from channel **588**. The operational surface, the cut-away area and channel **588** are within the focal zone **584'**. **570'** denotes the lens layer.

FIG. 34 depicts a preferred reverse optical disc assembly. The lens layer **590** focuses the laser beam **592** either on the reflective layer **594** or on the analyte **596**. The reflective layer **594** coats the operational structures located at the laser-proximal surface of the operational layer **604**. The analyte **596** resides in the analyte section which consists of the chamber **598**. The chamber **598** is laser-proximal to the operational structures and laser-distal to the lens layer. The adhesive layer **600** binds the operational layer **604** to the lens layer **590**. The channels **602** are etched into the operational layer **604**. Analytes can enter

and leave the analyte section **598** through channels **602**. The operational layer **604** is covered by the cover **606**. The operational structures and the analyte section are with the laser's focal zone **608**.

FIG. 35 demonstrates a forward optical disc assembly **618** which includes fluidic channels **616** and **620**. The operational layer **610** serves as a lens layer and is capable of focusing the laser beam **614** on the operational structures **612**. The operational structures **612** are located at the laser-distal surface of the operational layer **610**. Channels **616**, contained in the cover, can introduce analytes into the analyte section which includes the channel **620**. The channel **620** can be either laser-proximal or laser-distal to the operational structures. Both the operational structures and the channel **620** are within the focal zone **622**.

FIG. 36 shows a forward disc assembly **621** including a cut-away area **628** in the operational surface. The cut away area **628** is in the laser-distal surface of the operational layer **610'**, and preferably lacks operational structures or reflective coatings. Other areas in the laser-distal surface of the operational layer **610'** are contained with the operational structures **612'**. The channel **626** in the analyte section can be either laser-proximal or laser-distal to the cut-away area **628**. The focal zone **622'** encompasses the operational structures **612'**, the cut-away area **628**, and the channel **626**.

FIG. 37 illustrates a preferred embodiment of a forward optical disc assembly which includes analyte channels **666**. The analyte channels **666** are in or immediately above the lens layer **658**. These channels are connected to the analyte section **668**. The lens layer **658** is attached to the operational layer **662** through the adhesive layer **660**. The lens layer **658** is laser-proximal to the operational layer **662**. The operational structures at the laser-distal surface of the operational layer **662** are coated with a semi-reflective, semi-transmissive layer **664**. The analyte section **668** is configured to receive analytes **670**, and is located laser-distal to the semi-transmissive layer **664** and laser-proximal to another reflective layer **678**. The reflective layer **678**, which preferably is fully reflective, is laser-proximal to the cover **680**. Laser beam **676** can pass through the lens layer **658**, the adhesive layer **660**, the operational layer **662** and the semi-transmissive layer **664** to focus on the analytes **670** or the reflective layer **678**. The laser **676** can be reflected from the reflective layer **678**. The laser focal point can move across the focal zone **674**. Light reflected from layer **664** may carry operational information, whereas light reflected from layer **678** may carry investigational information.

FIG. 38 schematically demonstrates another embodiment of a forward optical disc assembly. The analyte section includes an analyte channel which can be located either laser-

proximal or laser-distal to the cut-away area **698**. The cut-away area **698** is at the laser-distal surface of the operational layer **692**. The cut-away area preferably lacks operational structures or reflective coatings. Other areas in the laser-distal surface of the operational layer **692** include the operational structures **694**. In FIG. 38, the cut-away area **698** is laser-proximal to the plane upon which the operational structures reside. Channels **696** are created in the cover layer of the disc assembly. Analytes or reaction components can enter or exit the analyte channel through channels **696**. The laser's focal zone **693** encompasses the operational structures **694**, the cut-away area **698**, and the analyte channel. One of skill in the art will appreciate that, in view of FIG. 38, the cut-away area **698** may also be located laser-distal to the plane upon which the operational structures are disposed.

FIG. 39 illustrates a preferred embodiment of a forward optical disc assembly including a cut-away area. The cut-away area is laser-proximal to the plane upon which the operational structures reside. The operational structures are positioned at the laser-distal surface of the operational layer **724**, and are coated by a reflective or semi-reflective layer **726**. The cut-away area preferably lacks operational structures or the coating **726**. The analyte section includes a chamber **728** which is etched into the operational layer **724**. The cut-away area constitutes the most laser-proximal surface of the chamber **728**. Fluidic flow **730** enters into the chamber **728** through channels **732** which cut through the cover layer **734**. A reflective layer **736** is located laser-proximal to the layer **734** but laser-distal to the operational structures. The laser **738** encounters and detects the first analytes **740** which are deposited on the cut-away area. The fluidic flow **730** may also mix the first analytes **740** with the second analyte **742**. The interaction between the analytes **740** and the analyte **742** may generate detectable signals. The laser's focal zone **744** encompasses the chamber **728**. As appreciated by one of skill in the art, channels **732** may be created with the operational layer **724**.

In one embodiment, the disc is a hybrid disc in that the operational surface includes at least two different formats of operational structures. For instance, the operational surface may include operational structures in a CD format as well as operational structures in a DVD format. The disc reader may read both formats. Data facilitating or regulating the disc reader to read different formats of operational structures may be encoded or embossed in the disc.

In a preferred embodiment, data other than operational structures can be encoded or embossed in the operational surface or other surfaces in the disc assembly. These data may provide control information for the disc reader to read or detect the investigational structures.

These data may regulate the measurement of investigational structures, for instance, by controlling valves which can manage fluidic flows in a fluidic circuit. These data, as well as the operational structures or other information, may be written to the disc before or after the investigational structures are read or detected.

The disc assembly may be used for detecting biological suspensions such as blood, urine, saliva, amniotic fluid, cerebrospinal fluid, synovial fluid, pleural fluid, pericardial fluid, perintoneal fluid. Environmental and chemical samples may also be assayed using the disc assembly. The disc assembly may include embossed features, placed features or etched features.

The disc assembly may be a null type disc, a modified disc based on industry standard disc, such as a modified CD-R or a modified CD, or a disc based on a custom format. Preferably, the disc assembly does not have the dye layer as used in a CD-R or a CD-RW disc.

In one embodiment, data used to identify the type of the disc assembly can be encoded in the disc assembly. For instance, a disc identification number (DIN) may be digitally encoded in the disc to describe the type of the operational layer, such as a forward wobble disc or a reverse wobble disc. The DIN may also be used to describe the design of the analyte section, the adhesive layer or the cover of the disc.

In another embodiment, the disc assembly includes an operational layer, an adhesive layer and a cover. The operational layer, the adhesive layer, or the cover of the disc may contain channels, cavities, slots, openings, or holes. The thickness of the adhesive layer may be between 25 and 500 micrometers, including within the range of about 25 micrometers to 100 micrometers, such as 50 micrometers. The adhesive material may be pressure sensitive, and can be made from acrylic or silicone. The cover layer may be coated with reflective materials such as gold.

An analyte chamber may be located within the adhesive layer. The operational layer or the cover may contain channels that are connected to the analyte chamber. Analytes, components reactive thereto or mediums can be introduced through these channels to the analyte chamber.

FIG. 40 illustrates an exploded perspective view showing the principle layers of a forward disc assembly according to one embodiment the present invention. The operational layer **966** is laser-proximal to the adhesive layer **958** which is laser-proximal to the cover **950**. The operational surface **968** is coated with a semi-reflective, semi-transmissive layer.

The operational layer **966**, the adhesive layer **958** and the cover **950** includes a central hole **964**, **962** and **954**, respectively. The disc assembly can be coupled to a disc reader through these holes, for example, by clamping to a motor shaft. The adhesive layer includes an opening **960**, which forms an analyte chamber when these layers are assembled together. The adhesive layer has a depth of about 100 micrometers. Investigational structures can be manipulated or retained in the analyte chamber formed by the opening **960**. The cover **950** includes the ports **952** and **956**. When the disc is assembled, these channels are connected to the analyte chamber **960**. Investigational structures or other reaction components may enter or exit from the chamber **960** through the ports **952** and **956**. Both the operational layer and the cover layer may be made from polycarbonate. The laser beam may pass through the disc assembly and be read by a top detector. Alternatively, a reflective layer may be coated at the laser-proximal surface of the cover **950** so that the laser beam can be reflected back therefrom.

As appreciated by one of skill in the art, a reverse wobble disc assembly can be similarly constructed as shown in FIG. 40. In addition, channels or openings, through which investigational structures or reaction components can be introduced into the analyte section, may be created in the operational layer. Operational structures may be created in the laser-proximal surface of the cover layer **950**.

Channels, cavities, inlet and vent ports, or other structures in the operational layer, the adhesive layer or the cover may be in a variety of configurations. FIG. 41 shows an operational layer **902** which has four slots **900**. FIG. 42 shows an adhesive layer **904** which has a series of openings **906**. These openings can form analyte chambers in the assembled disc. These different chambers may be connected to different channels located in either the cover layer or the operational layer. The assembled disc may perform different assays in different analyte chambers.

Data encoding design information that identifies the type of the disc assembly may be stored in the disc assembly and readable by the disc reader. Such information may also be printed on a surface of the disc assembly. For instance, a disc identification number (DIN) can be used to identify the type of the disc assembly. The number may include alphanumeric characters that are subdivided into different fields. One field may describe the main specifications of the operational layer. The main specifications include whether the disc is a reverse disc or a forward disc, and the particular disc design type for the operational layer. The main specifications may also include an identification number for the master of the

operational layer. A second field of the DIN may represent various modifications or other variables of the operational layer. The variables include the placement of the cut-away areas and the number of analyte chambers. In addition, the second field of the DIN may describe the position of the adhesive layer or techniques or materials used in making the disc assembly. The designs of the cover layer may also be described in the second field. A third field may include , which can be used to identify each disc. This serial number may be in the order of manufacture of the disc.

It should be understood that the above-described embodiments are given by way of illustration, not limitation. Various changes and modifications within the spirit and scope of the present invention will become apparent to those skilled in the art from the above description. In addition, the reader's attention is directed to the provisional applications from which the present application claims priority. The contents of all these provisional applications are incorporated herein by reference.